

# **The Identification of the Range of Ixodidae Ticks and the Epidemiological Evaluation of Lyme Disease and Spotted Fever Rickettsiosis in Kansas from 2008 to 2012**

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# Table of Contents

Abstract.....	1
Chapter 1: Tick-Borne Disease .....	2
Introduction .....	2
Chapter 2: Lyme Disease.....	3
Introduction .....	3
Case Classification .....	6
Purpose .....	8
Methods.....	9
Tick Vector Location.....	9
Epidemiological Study .....	9
Results.....	11
Tick Vector Locations .....	11
Epidemiology of Lyme Disease in Kansas, 2008-2012. ....	13
Discussion.....	20
Descriptive Epidemiology.....	20
Chapter 3: Spotted Fever Rickettsiosis .....	24
Introduction .....	24
Case Classification .....	27

Purpose .....	29
Methods.....	29
Tick Vector Location.....	29
Epidemiologic Study.....	29
Results.....	31
Tick Vector Locations .....	31
Epidemiology of Spotted Fever Rickettsiosis in Kansas, 2008-2012 .....	32
Discussion.....	39
Descriptive Epidemiology.....	39
Chapter 4: Conclusions .....	43
Study Limitations .....	43
Recommendations .....	44
Education .....	44
Bibliography .....	45

# Abstract

This study evaluates the presence of both Lyme disease and Spotted Fever Rickettsiosis tick vectors throughout the state of Kansas, as well provides a descriptive epidemiology of Lyme disease and Spotted Fever Rickettsiosis cases in Kansas from 2008 to 2012. Data used to create maps providing tick vector locations was gathered from unpublished and published literature sources that had previously identified the tick vector. Data regarding the number of probable and confirmed cases, age, gender, race, ethnicity, seasonality, exposure, and clinical presentation was gathered from two surveillance systems used by the Kansas Department of Health and Environment. Results show that the tick vector, *Ixodes scapularis*, has been moving and expanding over time, and is now found in 23 Kansas counties. Additionally, we see that *Dermacentor variabilis* is present in 57 counties in Kansas, while *Rhipicephalus sanguineus* has only been identified in 4 counties in Kansas. The epidemiology study shows that there is an above average incidence of Spotted Fever Rickettsiosis in Kansas compared to the incidence in the United States, while Lyme disease continues to remain below the reported incidence for the United States. Results would indicate that tick-borne disease is present and increasing in Kansas due to tick vector expansion and increased exposure to tick habitats.

Keywords: Lyme, Spotted Fever Rickettsiosis, *Ixodes*, ticks, location, Kansas, epidemiology

# Chapter 1: Tick-Borne Disease

## Introduction

Tick-borne diseases have been plaguing humans since the beginning of time. Scholars such as Cato, Aristotle, Pliny, and Homer have all referred to ticks in their writings, giving them negative connotations and regarding them as parasites (Edlow, 2002). Since the turn of the 20<sup>th</sup> century scientists and researchers have considered ticks as vectors for diseases, but they have more recently become a topic of serious research and study.

Tick classification is based on their exterior body structures. Hard bodied ticks are in the family Ixodidae and are characterized by their sclerotized dorsal shield. This group's habitat is a harsher, more open environment, like forests and prairies, where they attach to shrubs, trees, and grasses (Edlow, 2002). The Ixodidae family contains the most species of tick, with approximately 899 identified species worldwide, and approximately 90 of these species are present on the continental United States (Purdue University, 2008). These ticks are of great importance for public health. This family contains the tick species that cause many diseases such as Lyme disease, Spotted Fever Rickettsiosis, Tularemia, and Ehrlichiosis.

# Chapter 2: Lyme Disease

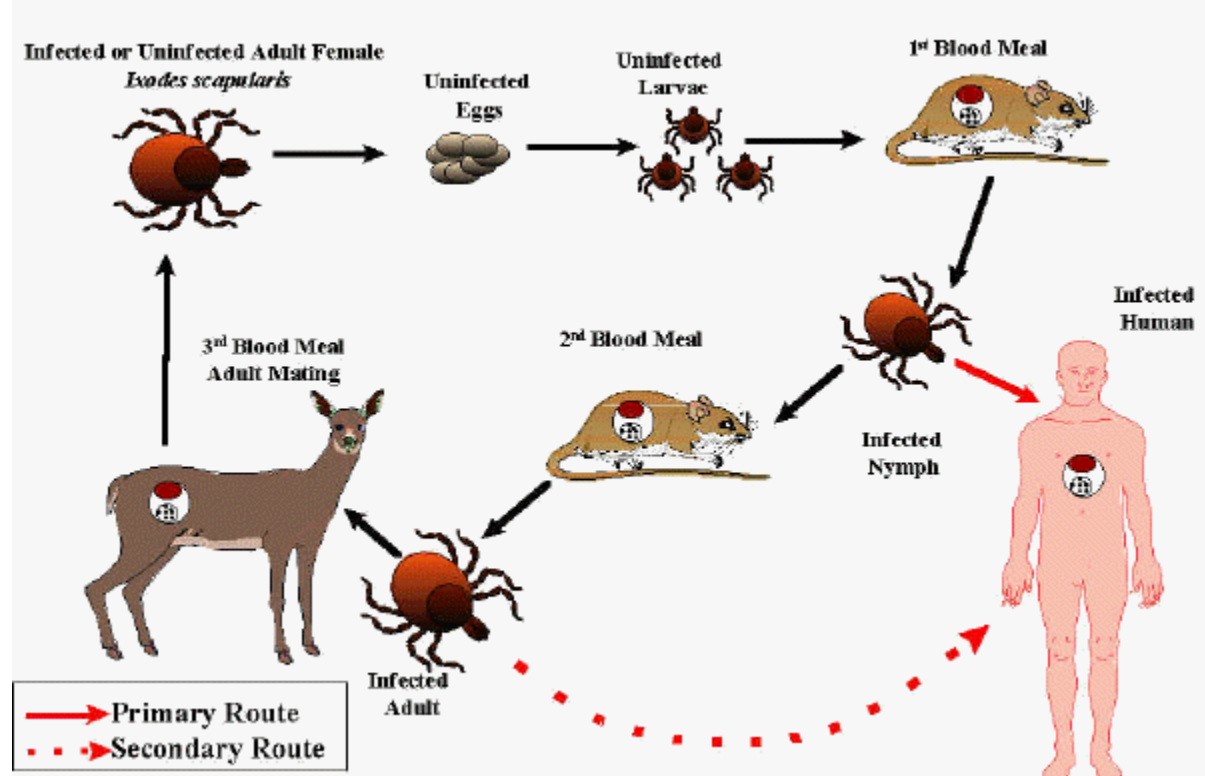
## Introduction

Lyme disease is caused by the bacterium *Borrelia burgdorferi*, which is passed in the saliva via bite from the tick to human host. The bacterium is a motile spirochete and an obligate intracellular pathogen. There are two types of ticks that are known to carry and transmit this bacterium. Both ticks are members of the Ixodidae family. The first is *Ixodes scapularis*, or the blacklegged or deer tick, which is the vector that is common in the Mid-Atlantic, Northeastern, and North Central regions of the United States. Secondly, there is the *Ixodes pacificus* or western blacklegged tick, which spreads Lyme disease along the West coast of the United States (Edlow, 2002).

The tick's habitat and ability to survive is largely dependent on climate, landscape, vegetation, and wildlife populations. The presence of *Ixodes scapularis* populations has been associated with deciduous, dry to mesic forests, and with alfisol-type soils, which are sandy or loam sand textures (Guerra, et al, 2002). Deciduous forests and these soil types are more commonly seen on the East Coast of the United States. In contrast, ticks are not common in grassland areas, conifer forests, wet to mesic forests, and acidic and clay texture soils (Guerra, et al, 2002). Kansas is composed of two primary types of biomes. One is the deciduous biome and the other is the grasslands biome (University of Kansas Natural History Museum and Biodiversity Institute, 2013). The grasslands area of Kansas is found in the western prairie regions, where vegetation and tree cover is sparse compared with the eastern region of the state, where there is tree cover with more seasonal precipitation and the annual dropping of leaves from trees as the seasons change.

The *Ixodes scapularis* tick has a two year life cycle, with four stages, egg, larvae, nymph, and adult; the life cycle is illustrated in Figure 1. The larvae, nymphs, and adults only feed once per stage and require several days to ingest each blood meal. *Ixodes* ticks are considered non-nidicolous, and will use the passive host finding strategy and questing behaviors to find a host as the blood meal source (Sonenshine, 1991). The first stage of the *Ixodes scapularis* life cycle is the egg stage. It is then followed by the second larval stage, which occurs after hatching from the egg. Hatching typically occurs from May to September each year. After the larvae have hatched and found a suitable host, they have their first blood meal and engorge in two to four days. *Ixodes scapularis* larvae typically feed on white-footed mice, other small mammals, birds, or lizards. At this stage the larvae may become infected with the bacteria *Borrelia burgdorferi* if it feeds from an infected host and can then infect subsequent hosts during later feedings. After the initial feeding is complete, the larvae molt into nymphs and stay dormant until the following spring. Once the spring arrives, the third stage occurs, which is the nymph life stage. The nymphs become active and partake in another blood meal feeding on a small mammal. The nymphs engorge in three to four days. If the nymph is infected, disease transmission may occur. If the nymph is not infected, it may acquire infection if feeding on an infected host. In the fall the nymphs turn into adults and take a third blood meal. Only at the adult stage is sexual dimorphism evident, and ticks can be distinguished as male or female. At the adult stage both male and female ticks feed. Once feeding has begun, gametogenesis is initiated, and the males and females mate. The female will then lay her eggs on larger mammals and then shortly thereafter dies (Sonenshine, 1991).

Figure 1: *Ixodes scapularis* Life Cycle Diagram.



(IMAGE: University of South Carolina, School of Medicine)

Once a person has been bitten by an infected tick, they may display acute clinical signs of Lyme disease within three to 30 days. One of the classic signs of Lyme disease is erythema migrans (EM), which is a large, red rash originating from the bite wound that can expand over a period of days to weeks, Figure 2. This rash is commonly referred to as a “bull’s eye” rash due to the unique shape and the central clearing that occurs during clinical disease progression. This is the most common clinical marker for Lyme disease, and can be seen in 60% to 80% of patients with Lyme disease (CDC, 2012). Persons with Lyme disease also can commonly display fever, chills, headache, facial or Bell’s palsy, joint and muscle aches, and swollen lymph nodes (CDC, 2012). Even months to years after the infective bite has occurred, patients experience chronic symptoms such as arthritis, muscle and joint pain, cognitive defects, and fatigue (CDC, 2012).



**Figure 2: Erythema Migrans Rash**



(IMAGE: CDC)

## **Case Classification**

Lyme disease became a nationally notifiable disease in 1991 and is still currently monitored on the state and national level. According to the CDC, in 2011, Lyme disease is the most commonly reported vector-borne illness in the U.S. and the 6th most common nationally notifiable disease.

States classify Lyme disease cases based on case definitions that are decided upon by state epidemiologists at the Council of State and Territorial Epidemiologists annual meeting. Reported cases are submitted electronically to the CDC. Case definitions allow states to uniformly classify cases in order to accurately quantify and track cases of reportable diseases. For Lyme disease the CDC utilizes three classifications: confirmed, probable, and suspect based on clinical presentation of the disease, laboratory tests, and exposure.

The clinical presentation of Lyme disease includes erythema migrans rash (EM), and other acute symptoms such as fever, fatigue, headache, mildly stiff neck, arthralgia, and myalgia. Late stage manifestations include chronic arthritis and other musculoskeletal system symptoms; neurological

involvement including lymphocytic meningitis, cranial neuritis, facial palsy, radiculoneuropathy, and rarely encephalomyelitis; or cardiovascular system involvement including acute onset of high grade atrioventricular conduction defects which may be associated with myocarditis.

The laboratory criteria for Lyme disease diagnosis and confirmation can include the following tests (MMWR, 1995):

- Positive culture of *B. burgdorferi* from a site of infection.
- Two-tier testing procedure.
  - A positive enzyme immunoassays (EIA) or immunoflorescent assay (IFA), with  
EITHER
    - A positive IgM western blot within 30 days of symptom onset- if two of the following three bands are detected: 24kDa, 39kDa, and 41kDa.
  - OR
    - A positive IgG western blot at any point during illness- if five of the following ten bands are present: 18kDa, 21kDa, 28kDa, 30kDa, 39kDa, 41kDa, 45kDa, 58kDa, 66kDa, and 93kDa.
  - A single positive IgG EIA or IFA from cerebral spinal fluid (CSF) that is positive for *B. burgdorferi* when the titer is higher in the CSF than it was in the serum.

The last criterion evaluates the patient's exposure. In order to be considered exposed, the patient must have been in a wooded, brushy, or grassy area within 30 days before the onset of the EM rash and in a county where Lyme disease is considered endemic. An endemic county is one in which two confirmed cases have been reported or there are established populations of the tick vector that are known to be infected with *B. burgdorferi* (CDC, 2011).

For a confirmed case one of three criteria must be met:

- EM rash with a known exposure (as defined above) in an endemic county.
- EM rash with laboratory evidence of infection (as defined above) and without a known exposure.
- One late manifestation with laboratory evidence of infection.

For a probable case:

- A physician must diagnose Lyme disease and have laboratory evidence of infection.

For a suspect case:

- A case of EM where is no known exposure (as defined above) and no laboratory evidence of infection (as defined above), OR
- A case with laboratory evidence of infection but no clinical information (e.g., only a laboratory report).

## **Purpose**

The first objective was to evaluate the literature as well as other sources to determine counties in Kansas where the tick vector, *Ixodes scapularis*, have been reported. The second objective was to collect data from the KDHE's electronic disease surveillance systems and complete a descriptive epidemiologic study from Lyme disease cases reported in Kansas from 2008 to 2012. The third objective was to identify counties of exposure for confirmed cases in order to determine if any Kansas counties would be considered endemic based on the CDC case definition.

# Methods

## Tick Vector Location

The primary data used for creating the map of counties where the *Ixodes scapularis* vector has been identified was obtained from Dr. Michael Dryden, a faculty member of Kansas State University's College of Veterinary Medicine. The data were collected through a passive collection method, and contained tick submissions from the general public for identification from the years 2000 to 2012. Additional data came from both published and unpublished literature (Dryden, 2012, Brillhart, 1993, White & Mock, 1991, & Anderson, Unpublished data). ArcMap 10.1 was used to produce the Kansas county maps depicting the tick vector locations.

## Epidemiological Study

The time period selected for the Lyme disease study include all probable and confirmed cases that were submitted between January 1<sup>st</sup>, 2008 and December 31<sup>st</sup>, 2012. The data for Lyme disease was collected from the KDHE's two surveillance systems. The Kansas Electronic Disease Surveillance System (KS-EDSS) contained all case data for Lyme disease reports submitted from January 1<sup>st</sup>, 2008 to December 31<sup>st</sup>, 2011 and the current surveillance system EpiTrax, collected data for Lyme disease cases reported, from January 1<sup>st</sup>, 2012 to December 31<sup>st</sup> 2012. The variables that were studied included the number of probable and confirmed cases, age, gender, race, ethnicity, seasonality, exposure, and clinical presentation.

Incidence was calculated as follows:

$$\frac{\begin{array}{l} \text{\# of new cases of disease occurring in the population} \\ \text{\underline{during a specified time period}} \end{array}}{\begin{array}{l} \text{\# of persons who are at risk of developing the disease} \\ \text{during that time period} \end{array}} \times 100,000$$

The national data used to calculate incidence was obtained for Lyme disease cases from the MMWR Annual Summary of Notifiable Diseases, and the number of cases for Kansas was obtained from data collected through the KDHE's surveillance system. The population data was obtained from the U.S. Census Bureau's website for both the United States and Kansas populations. The nationally reported number of Lyme cases has not been published by the CDC for the years 2011 and 2012, and therefore the national incidence cannot be calculated for those years. Incidence between Kansas and the United States can only be compared for the years 2008, 2009, and 2010.

The seasonality data used the month that the case was reported to public health. Date reported to public health was used to ensure completeness of data, because all 103 cases of Lyme disease had a report date to public health listed in the surveillance system as compared to the onset of illness date, which was not reported in all cases.

To obtain the number and percentages for case classification, gender, race, ethnicity, age, county and state of exposure, exposure to a tick habitat, and the number of cases with clinical symptoms of Lyme disease, the PROC FREQ procedure in SAS 9.2® was utilized.

# Results

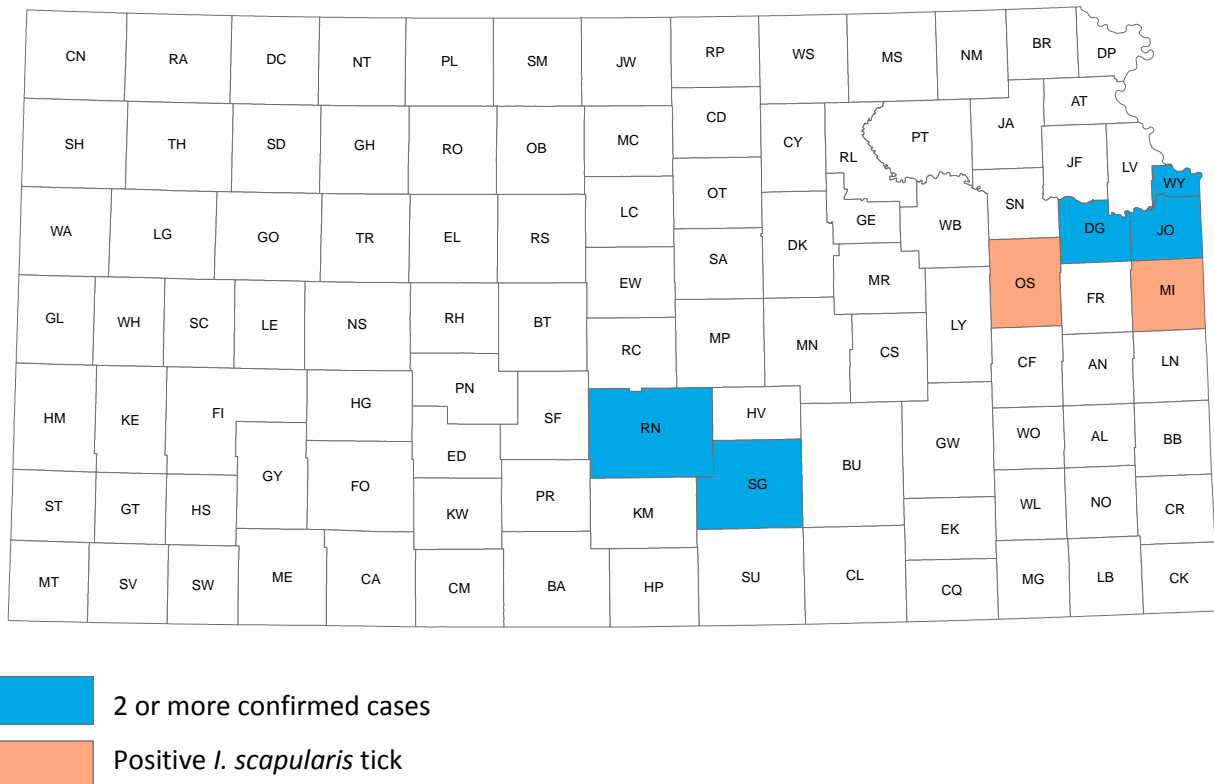
## Tick Vector Locations

*Ixodes scapularis* was identified in 23 counties in Kansas, including Riley, Johnson, Miami, Linn, Bourbon, Crawford, Cherokee, Jefferson, Douglas, Franklin, Anderson, Neosho, Labette, Montgomery, Woodson, Osage, Shawnee, Greenwood, Elk, Chautauqua, Cowley, Butler, and Marion County. The *Ixodes scapularis* tick was not reported from any counties west of Marion County. Before 1988, there were only two records of *I. scapularis* in Kansas, one in 1949 and the other in 1980; both collected in Cherokee county which is located in the extreme southeast corner of the state (White and Mock, 1991). After 1988, White and Mock reported *I. scapularis* from Douglas, Labette, and Jefferson counties which increased the known range of *I. scapularis* northward by 240 km (White and Mock, 1991). In 2003, *I. scapularis* was reported in Anderson, Butler, Elk, Neosho, and Osage counties (Anderson, Unpublished Data).

A map of Georgia showing the distribution of *I. scapularis*. The map is divided into counties, each labeled with a two-letter code. A legend in the bottom left corner shows a blue square next to the text "Counties with *I. scapularis*". The counties shaded in blue are: RL, MN, BU, CL, CQ, MG, LB, CK, CR, NO, WL, GW, WO, AL, BB, LN, AN, FR, MI, JO, DG, JF, LV, WY, AT, and PT.

12

**Figure 4: Endemic Counties in Kansas.**

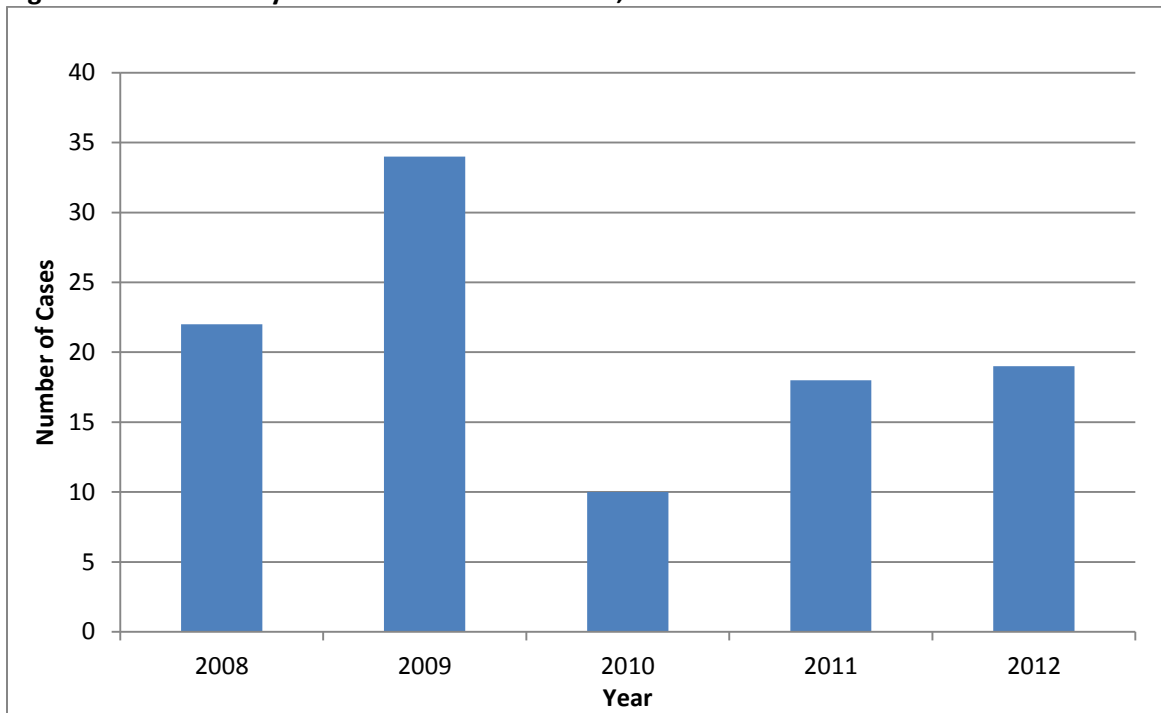


## Epidemiology of Lyme Disease in Kansas, 2008-2012.

A total of 103 confirmed and probable cases of Lyme disease were reported in Kansas from 2008-2012. In 2008 there were 22 cases, in 2009 there were 34 cases, in 2010 there were 10 cases, in 2011 there were 19 cases, and in 2012 there were 18 cases, Figure 5.

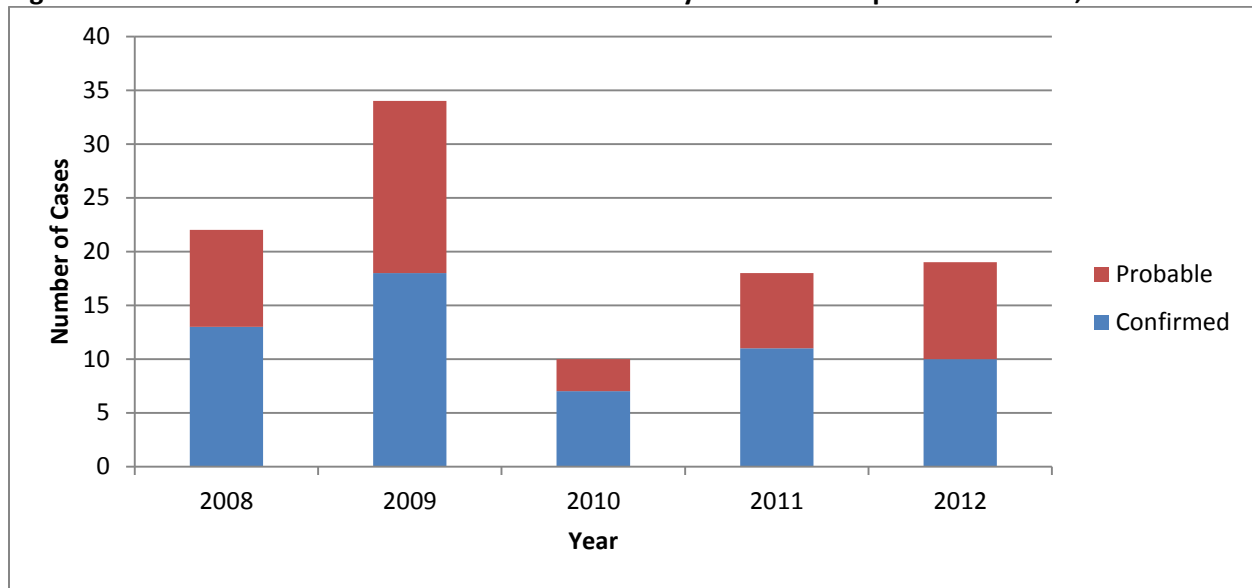


**Figure 5: Number of Lyme Disease Cases in Kansas, 2008-2012.**



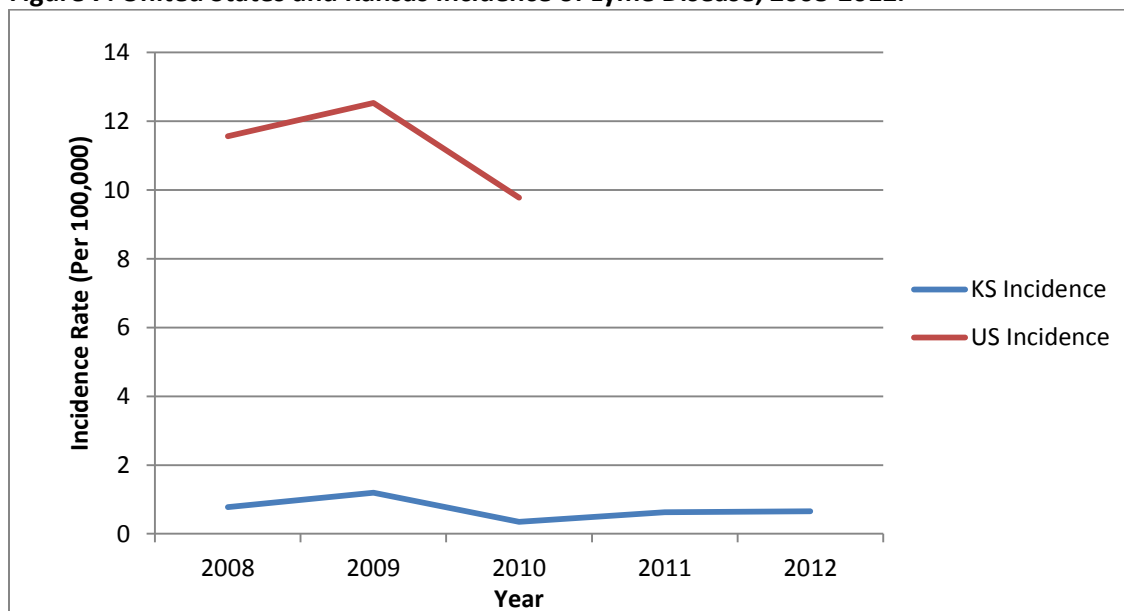
In 2008, there were 13 confirmed and 9 probable cases, in 2009 there were 18 confirmed and 16 probable cases, in 2010 there were 7 confirmed cases and 3 probable cases, in 2011 there were 11 confirmed cases and 7 probable cases, and in 2012 there were 10 confirmed cases and 9 probable cases, Figure 6. Over the 5 year period, from 2008 to 2012 there were 59 (57%) confirmed cases and 44 (43%) probable cases reported in the state of Kansas.

**Figure 6: Number of Confirmed and Probable Cases of Lyme Disease Reported in Kansas, 2008-2012.**



The incidence of Lyme disease in the United States was 11.56 in 2008, 12.53 in 2009, and 9.77 in 2010. The incidence in Kansas was considerably lower and was 0.78 in 2008, 1.2 in 2009, 0.35 in 2010, 0.63 in 2011, and 0.66 in 2012, Figure 7.

**Figure 7: United States and Kansas Incidence of Lyme Disease, 2008-2012.**



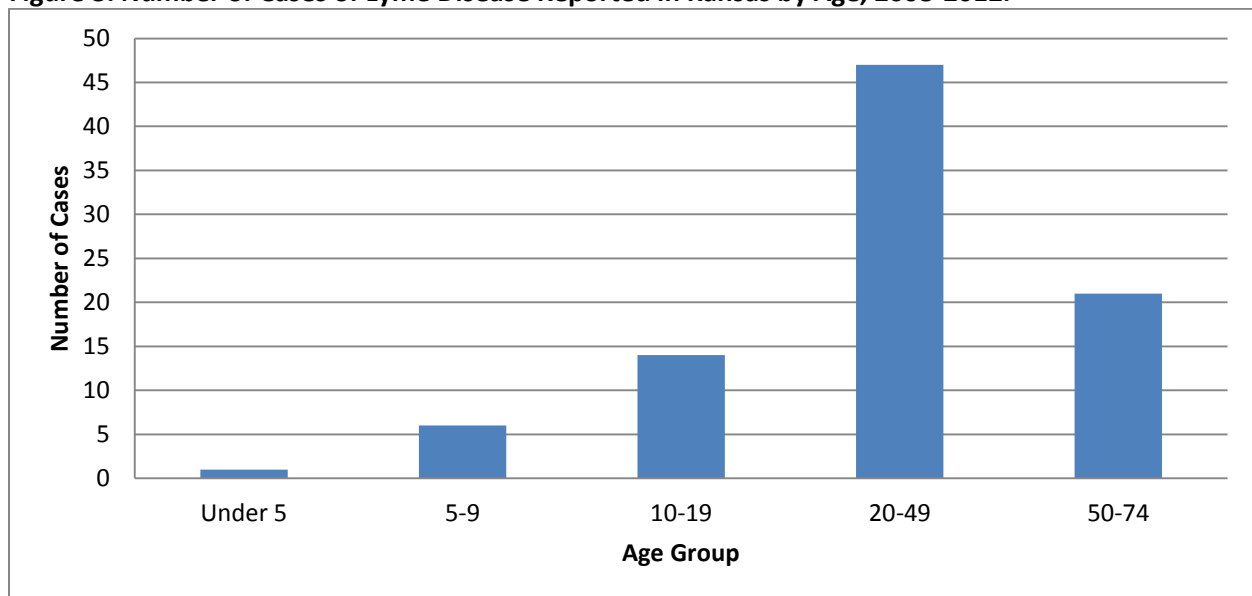
From 2008-2012, there were more male cases of Lyme disease reported than female cases, Table 1. Race was reported for 78 cases of Lyme disease from 2008 to 2012; race was not reported and is considered unknown for 25 cases, Table 1. The predominant race affected was White 73, followed by Black/African-American. Only one Lyme disease case was reported as Asian or Hawaiian/Pacific Islander. Ethnicity was reported for 68 Lyme disease cases from 2008 to 2012; ethnicity was not reported and is unknown for 35 cases, Table 1. There were significantly more non-Hispanic/Latino individuals with Lyme disease reported than individuals of Hispanic/Latino ethnicity.

**Table 1: Demographic Characteristics of Lyme Disease Patients in Kansas, 2008-2012.**

Demographic	Number	Percentage
<b>Sex</b>		
Male	61	59.22
Female	42	40.78
<b>Race</b>		
White	73	70.87
Black/African American	3	2.91
Native Hawaiian/Pacific Islander	1	0.97
Asian	1	0.97
Unknown	25	24.27
<b>Ethnicity</b>		
Non-Hispanic or Latino	66	64.08
Hispanic or Latino	2	1.94
Unknown	35	33.98

From 2008 to 2012 Lyme disease was most commonly reported in adults 20 to 49 years old, Figure 8. Individuals 50 to 74 years old had the next highest number of cases followed by children 10 to 19 years. Few cases were reported in children that were 0 to 5 years old. There were 14 cases that did not have a documented onset date, and therefore age at onset was not calculated.

**Figure 8: Number of Cases of Lyme Disease Reported in Kansas by Age, 2008-2012.**



The clinical presentation of those individuals with Lyme disease reported from 2008 to 2012 is shown in Table 2. The acute symptoms seen most commonly in patients were EM rash, fatigue, headache, fever, arthralgia, myalgia, and neck pain.

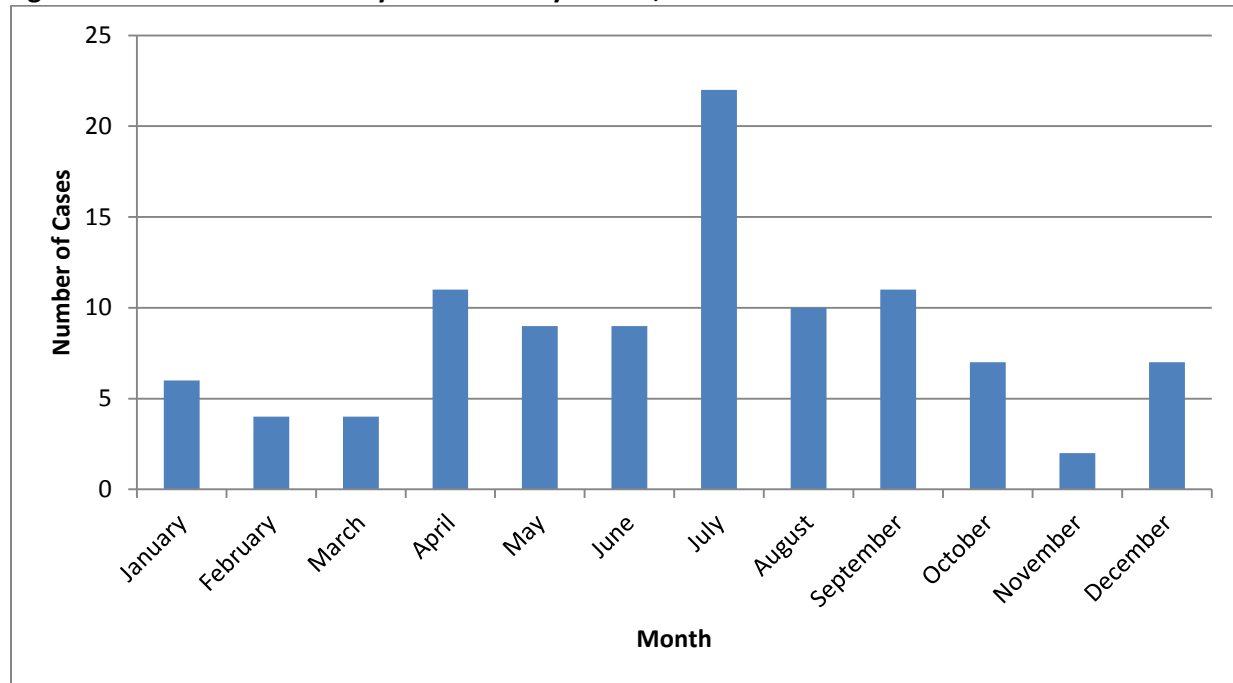
The chronic or late manifestation symptoms are broken down into the body system that is affected; this includes the musculoskeletal system, nervous system, and cardiovascular system.

**Table 2: Clinical Manifestations of Lyme Disease.**

Acute Symptoms	Number of Cases
Erythema Migrans	36
Fatigue	34
Headache	24
Fever	23
Arthralgia	20
Myalgia	18
Neck Pain	6
Chronic Symptoms	Number of Cases
Musculoskeletal System	38
Nervous System	26
Cardiovascular System	2

Thirteen cases (13%) reported that they were hospitalized and hospitalization was unknown for only two cases. No deaths were reported from Lyme disease from 2008 to 2012.

**Figure 9: Number of Cases of Lyme Disease by Month, 2008-2012.**



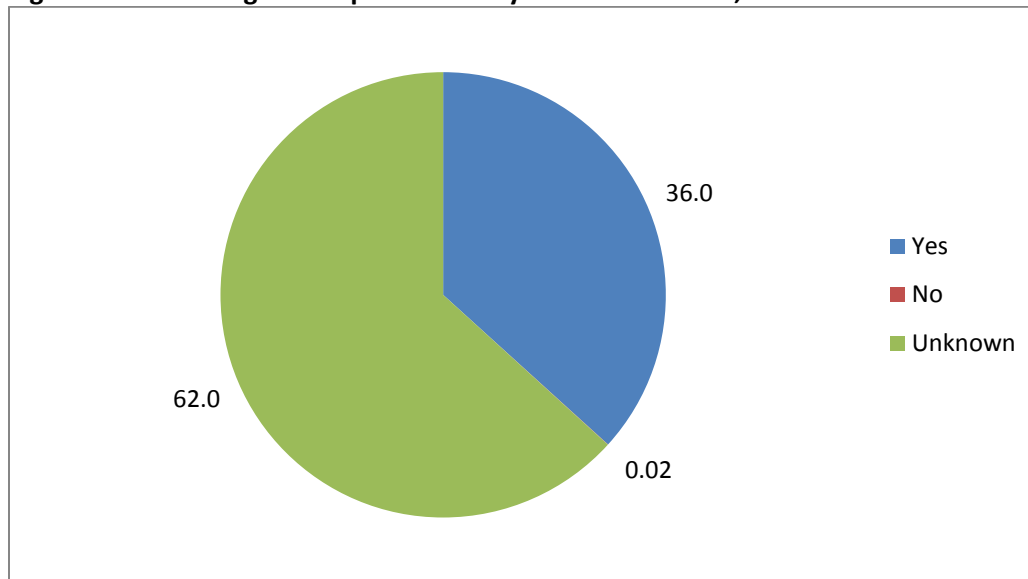
A majority of Lyme disease cases are reported between April and October of each year, with the highest number of cases reported in July, displaying a late spring to early fall seasonality, Figure 9.

There were a total of 22 counties in Kansas where a confirmed and/or probable case of Lyme disease reported exposure from 2008 to 2012. These counties included Bourbon, Cherokee, Cowley, Crawford, Douglas, Ellis, Jefferson, Johnson, Kingman, Labette, Linn, Marshall, Montgomery, Neosho, Reno, Riley, Saline, Sedgwick, Shawnee, Stafford, Wabaunsee, and Wyandotte County, Figure 10. For the 103 cases of Lyme disease reported from 2008 to 2012, 59 (73%) reported exposure in Kansas, 22 cases (27%) reported an out of state exposure that included Arkansas, California, Colorado, Maine, Maryland, Minnesota, Missouri, Nebraska, New York, Oklahoma, and Pennsylvania. Twenty-two cases either did not report place of exposure or their place of exposure is unknown.

Counties of Exposure for Confirmed and Probable Cases

19

**Figure 11: Percentages of Exposures for Lyme Disease Cases, 2008-2012.**



## Discussion

### Descriptive Epidemiology

Prior to 1988, Cherokee county was the only county in Kansas to have had *I. scapularis* identified (White and Mock, 1991). This county is located in the south east corner of the state, bordering both Missouri and Oklahoma. This geographical location is important, because Missouri reported indigenous cases of Lyme disease prior to 1988 (MMWR, 1989). By 2012, *I. scapularis* has been reported in 23 counties in Kansas. This could indicate a north and westward expansion of the known location of *I. scapularis*. These results support research indicating that the most suitable regions for the establishment of *I. scapularis* populations are in the eastern portion of the state because the deciduous forest biome can support the life cycle and maintain a habitat suitable for *I. scapularis*. The reason for the expansion of the *I. scapularis* into Kansas is not known; however, warming climates and the effects on their location and concentration of their host's populations are likely factors.

Prior to this study, no county in Kansas was considered endemic for Lyme disease. At the conclusion of this study there are seven counties that are now considered endemic, five had two or more confirmed cases of Lyme disease with reported exposure in those counties, while *I. scapularis* ticks infected with *B. burgdorferi* were identified in two additional counties. It is important to note that both Reno and Sedgwick County are now considered endemic, despite *I. scapularis* not being found previously in those counties, but because two or more confirmed cases reported exposure there they will be considered endemic. Also, since the collection of ticks was through passive surveillance *I. scapularis* may actually be present in these counties. Further studies to determine the true range of this vector should be performed.

Individuals with confirmed and/or probable cases of Lyme disease with no travel record have reported exposure in Ellis, Reno, Saline, Stafford, Sedgwick, Kingman, Marshall, Wabaunsee, and Wyandotte Counties. These nine counties have not had *I. scapularis* identified there. Ellis County has reported one confirmed case of Lyme disease, in 2009. This result is unusual, because this county is located much further west than the tick vector is primarily seen. Additionally, the patient did not report travel within 30 days of symptom onset, and therefore it is assumed that his only opportunity for exposure occurred within Ellis County. This case may be indicative of the further spread of the *Ixodes scapularis* tick westward, despite unfavorable environmental conditions.

In 2009 there was an increase in the number of reported Lyme disease cases compared to 2008, 2010, 2011, and 2012. Subak et al. has reported that a higher moisture index measured by the Palmer Drought Severity Index (PDSI) from the summer two years prior may be correlated with an increase in Lyme disease incidence. The PDSI from July of 2006 is -2.40, indicating low moisture compared with the PDSI from July of 2007 which is 3.47 indicating an increase in moisture, two years prior to the increase of



Lyme disease cases in 2009. Increased moisture in an area will enhance nymph tick survival, due to wetter conditions (Subak et al, 2003).

There were slightly more males than females with reported Lyme disease. This result might be due to males being more active outdoors by participating in ranching and farming activities as compared to women, but more research is needed to understand this distribution. Most individuals with reported Lyme disease were 20-49 years old. Perhaps this age group has a greater and more prolonged outdoor exposure in woody and brushy areas or could have travel to counties or states that have endemic populations of *I. scapularis*, which are both major risk factors in contracting Lyme disease. The second highest group with reported Lyme disease is the 50 to 74 year olds. This can also be explained that those on the lower end of the spectrum of this age group, below 65, are still active and may frequently participate in outdoor activities like walking, hiking, gardening, hunting, or fishing. A majority of Lyme disease cases reported their race as white, while very few cases were reported from other races. This closely mimics the race breakdown for Kansas with the U.S. Census Bureau, in 2011, reported that 87.4% of the total Kansas population is white, while only 6.1% of Kansans are black, 2.5% are Asian, 1.2% are American Indian/ Alaska Natives, and 0.1% are Pacific Islander.

Kansas's incidence is much lower than the national incidence for Lyme disease which is not surprising due to the fact that over half of the state has climate and habitat conditions that would not support the establishment of populations of *I. scapularis* ticks. The CDC reports that in 2011, 96% of all Lyme disease cases in the U.S. came from thirteen states; Connecticut, Delaware, Maine, Maryland, Massachusetts, Minnesota, New Hampshire, New Jersey, New York, Pennsylvania, Vermont, Virginia, and Wisconsin (CDC,2011). All of these Eastern states possess the deciduous forest biome that supports the life cycle of *I. scapularis*. Typical features of north eastern states include statewide prevalence of deciduous trees like Maple, Oak, Elm, Aspen, and Birch trees, which annually lose their leaves and create

a leaf litter, which is favorable for *I. scapularis*. Additionally, these north eastern states have large statewide populations of mammals like the white-tailed deer, raccoons, and opossums, which are hosts for *I. scapularis* during their blood meal feeding, compared to Kansas where these species are predominantly found only in the eastern region of the state. Lastly, acorns are an important part of the diet of the white-footed mouse, which is the primary host for the *I. scapularis* nymphs. Oak trees which drop these acorns make up a large portion of the deciduous forest biome. With the high levels of acorns, this mouse species and *I. scapularis* tick are able to thrive in north eastern states (Subak et al, 2003).

The reports of Lyme disease from 2008 to 2012 show a seasonality with more Lyme disease cases being reported between April and October. People are more likely to be participating in outdoor activities during the spring, summer, and early fall months when ticks are active and feeding. This result is expected and mimics the same seasonality trend seen in Lyme disease cases in the United States.

# Chapter 3: Spotted Fever Rickettsiosis

## Introduction

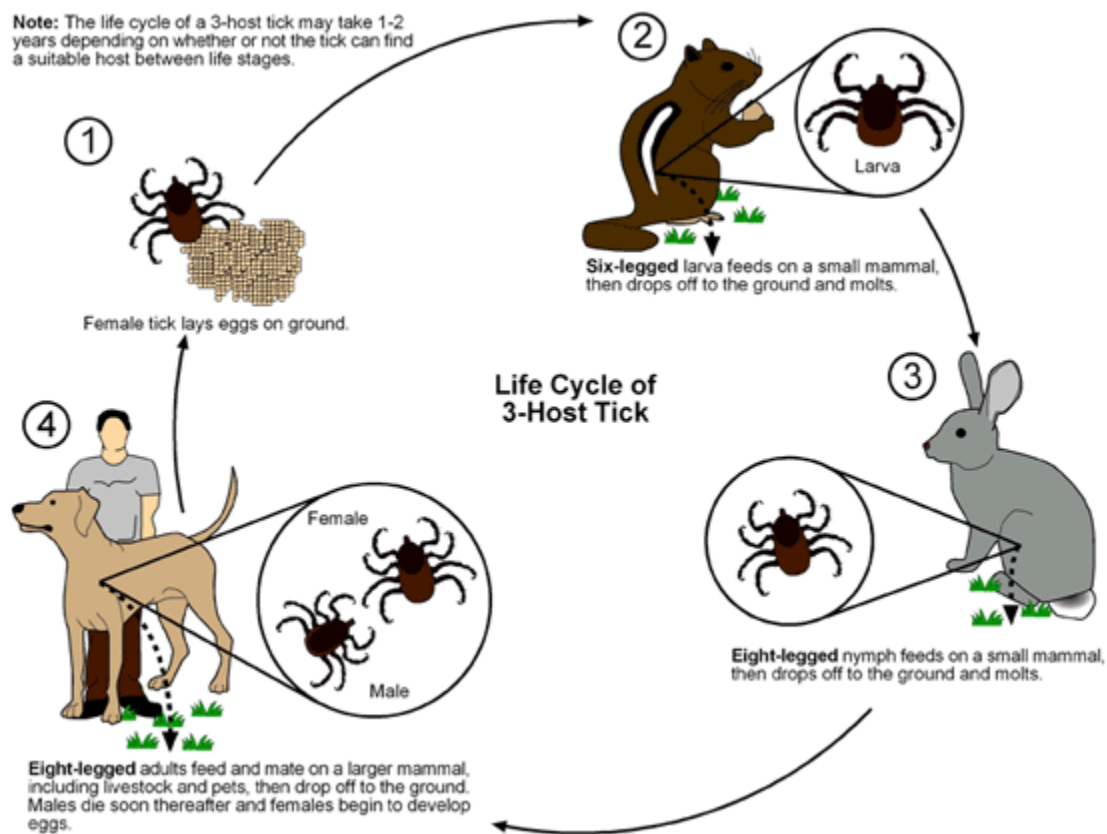
Spotted Fever Rickettsiosis is caused by the bacteria *Rickettsia spp.* Bacteria from these species are gram negative rods, obligate intracellular pathogens, and have a tropism for endothelial cells (Edlow, 2002). The bacteria are transferred to the human host from the saliva that is released from a tick during a blood meal feeding.

Spotted Fever Rickettsiosis is transmitted by three different species of ticks; the American dog tick- *Dermacentor variabilis*, the Rocky Mountain wood tick- *Dermacentor andersoni*, and the Brown dog tick- *Rhipicephalus sanguineus*, which are all within the Ixodidae family. The presence of the *D. andersoni* tick vector is primarily found in the Rocky Mountain States. *D. variabilis* has a widespread distribution in the United States, covering the entire east coast to the Rocky Mountains. It also has a presence in limited areas along the west coast. *R. sanguineus* is found in all 50 states (CDC, 2012).

The life cycle for *D. variabilis* includes four life stages, egg, larva, nymph, and adult, Figure 12. The entire life cycle for this tick species can be as short as 3 months in warm, southern climates or as long as 2 years in more northern climates (CDC, 2012). For Kansas, which tends to be a colder climate, the life cycle would typically be closer to 2 years. The first stage of the life cycle is completed when the eggs hatch within 15 to 60 days after being laid. Once hatched, the larvae have their first blood meal and stay attached, feeding for three to 12 days. Typical hosts for larva include voles, mice, and other small mammals. After feeding, the larvae become dormant and will molt in six to 250 days emerging as nymphs. Nymphs will then have their second blood meal, staying attached to their host and feeding for three to 11 days. Nymphs will feed on larger mammals, such as cats, dogs, opossums, rabbits, and

raccoons. Once the second feeding is complete, they again become dormant and will molt into an adult 16 to 300 days later. At the adult stage, the females will have a final blood meal, staying attached and feeding for four to 10 days on larger mammals such as, cats, coyotes, dogs, cattle, horses, raccoons, and humans. Soon after the females will lay their eggs and then die. The adult males do not have a third blood meal (Sonenshine, 1991).

**Figure 12: *Dermapentor variabilis* Life Cycle.**

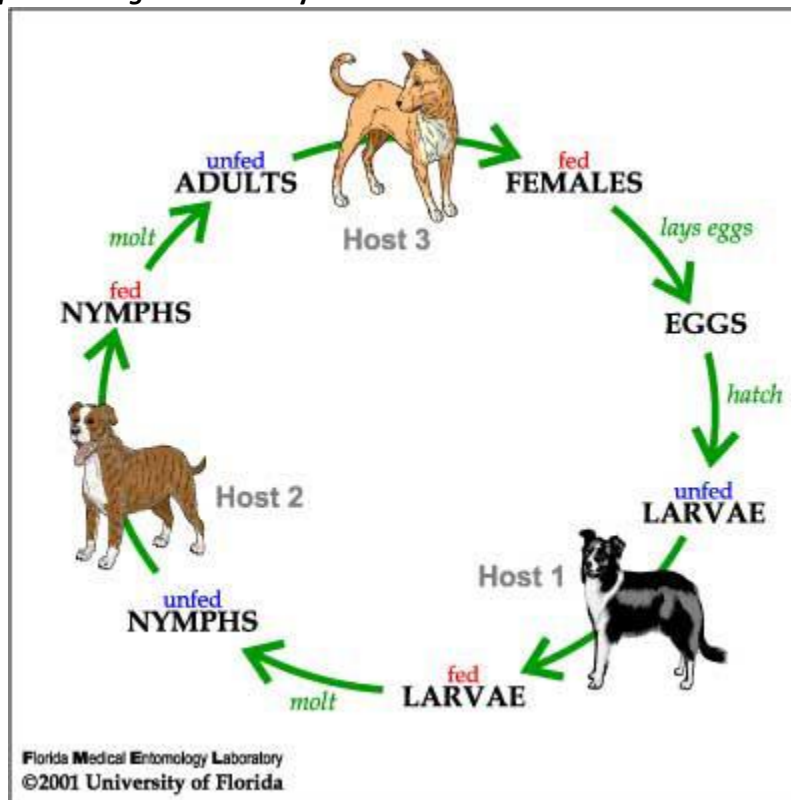


(IMAGE: Purdue University)

The *R. sanguineus* tick species, also known as the American dog tick, has a similar life cycle to *D. variabilis*, Figure 13. The eggs will hatch 17 to 30 days after being laid, and emerge in the larval stage. At the larval stage they take their first blood meal and will feed for two to seven days. They lie dormant and will molt five to 23 days later. Once this molting occurs, they emerge as nymphs and have their

second feeding, taking typically four to nine days. Then they lie dormant and will molt a final time 11 to 73 days later. After this final molting they emerge as adults, and will have their third blood meal staying attached and feeding for six to 19 days. Females will lay their eggs prior to their death. The *R. sanguineus* tick almost exclusively feeds on canines. The larval and nymph stages prefer to feed on dogs, but will also feed on other small mammals, such as rabbits or rodents. At the adult stage they also prefer to feed on dogs, and will rarely feed on other mammals (CDC, 2012). Like the *D. variabilis* tick, these ticks may become infected by having a blood meal from an infected host, and therefore will be able to transmit the *Rickettsia* spp. during any subsequent feeding from the time of infection.

**Figure 13: *Rhipicephalus sanguineus* Life Cycle.**



(IMAGE: University of Florida)

Symptoms of Spotted Fever Rickettsiosis include the sudden onset of fever, headache, nausea, vomiting, abdominal pain, muscle pain, lack of appetite, conjunctivitis, or redness of the eyes, and rash

(CDC, 2012). Rash occurs in 90% of individuals diagnosed with Spotted Fever Rickettsiosis, and commonly occurs two to five days after the onset of the fever. The rash typically forms small, flat, pink, non-itchy macules along the wrists, forearms, and ankles. Occasionally the rash may spread to the torso of the body, along with the palms of the hands and the soles of the feet. Approximately 35% to 60% of those with rashes will present as petechial rashes. These are red to purple in color, and give the individual a more spotted appearance. These are usually not seen until the sixth day or later after the first symptoms appear. Petechial rash usually indicate a more severe case of Spotted Fever Rickettsiosis (CDC, 2012). Eschar at the site of the bite can occur with infection from other *Rickettsia* species and can often be used to differentiate between RMSF and other rickettsial diseases.

Rocky Mountain Spotted Fever has been on the Nationally Notifiable Disease list since the 1920's, but in January, 2010, it was merged into a category known as Spotted Fever Rickettsiosis. This new listing includes a group of tick-borne infections caused by several members of the genus *Rickettsia*. This was done because these serologic tests which are commonly used to diagnose RMSF will also cross react with other *Rickettsia* species. Because of this, some reported cases of RMSF may actually be caused by a different rickettsial infection; therefore, it was more aptly named Spotted Fever Rickettsiosis to include several diseases (MMWR Annual Summary, 2010).

## **Case Classification**

States classify Spotted Fever Rickettsiosis cases based on case definitions that are decided upon by state epidemiologists at the Council of State and Territorial Epidemiologists annual meeting. These cases are submitted electronically to the CDC. Case definitions allow states to uniformly classify cases in order to accurately quantify and track cases of reportable diseases. For Spotted Fever Rickettsiosis the CDC also utilizes three classifications: confirmed, probable, and suspect based on clinical presentation of the disease, laboratory tests, and exposure.

In order for a case to be confirmed:

- Must have a clinically compatible case and be laboratory confirmed.

In order for a case to be considered probable:

- Must be a clinically compatible case, AND
- Have supportive laboratory results.

In order to be considered a suspect case:

- The case must have laboratory evidence of past or present infection, but no clinical information is available.

The confirmed laboratory criteria for Spotted Fever Rickettsiosis diagnosis and confirmation can include the following four tests:

- Four-fold increase in IgG antibody titer through the use of direct immunofluorescence assay (IFA).
  - Performed on paired serum samples, the first sample taken during the first week of illness and the second sample taken two to four weeks later after onset of illness.
- Detection of *R. rickettsia* or other spotted fever group DNA in clinical specimen via amplification of a specific target by PCR assay.
- Demonstration of spotted fever group antigen in a biopsy or autopsy specimen by immunohistochemistry (IHC).
- Isolation of *R. rickettsia* or other spotted fever group rickettsia from a clinical specimen in cell culture.

Only confirmed and probable cases are reported to the CDC.

## **Purpose**

The first objective of this project included conducting a literature review and collecting retrospective data on counties in Kansas where *Dermacentor variabilis* and *Rhipicephalus sanguineus* ticks have been reported. The second objective of this the study was to collect data from the KDHE's surveillance systems and complete a descriptive epidemiological study about the Spotted Fever Rickettsiosis cases reported from 2008 to 2012 in the state of Kansas.

## **Methods**

### **Tick Vector Location**

The primary data used for creating the map of the *Dermacentor variabilis* and *Rhipicephalus sanguineus* vectors was obtained from Dr. Michael Dryden, a faculty member of Kansas State University's College of Veterinary Medicine. The data were collected through a passive collection method, and contained tick submissions from the general public for identification from the years 2000 to 2012. Additional data came from both published and unpublished literature (Dryden, 2012, Brillhart, 1993, White & Mock, 1991). ArcMap 10.1 was used to produce the Kansas county maps depicting the tick vector locations.

### **Epidemiologic Study**

The time period that was selected for the Spotted Fever Rickettsiosis study included all probable and confirmed cases that were reported between January 1<sup>st</sup>, 2008 and December 31<sup>st</sup>, 2012. The data for Spotted Fever Rickettsiosis was collected from the KDHE's two surveillance systems. The Kansas Electronic Disease Surveillance System (KS-EDDS) contained all case data for Spotted Fever Rickettsiosis



for reports submitted from January 1<sup>st</sup>, 2008 to December 31<sup>st</sup>, 2011 and the current surveillance system, EpiTrax was utilized to collect data for Spotted Fever Rickettsiosis, for reports submitted from January 1<sup>st</sup>, 2012 to December 31<sup>st</sup> 2012. The variables that were studied included the number of probable and confirmed cases, age, gender, race, ethnicity, seasonality, exposure, and clinical presentation.

Incidence was calculated as follows:

$$\frac{\begin{array}{l} \text{\# of new cases of disease occurring in the population} \\ \text{\underline{during a specified time period}} \end{array}}{\begin{array}{l} \text{\# of persons who are at risk of developing the disease} \\ \text{during that time period} \end{array}} \times 100,000$$

The national data used to calculate incidence was obtained for Spotted Fever Rickettsiosis cases from the MMWR Annual Summary of Notifiable Diseases, and the number of cases for Kansas was obtained from data collected through the KDHE's surveillance systems. The population data was obtained from the U.S. Census Bureau's website for both the national and Kansas populations. The nationally reported number of Spotted Fever Rickettsiosis cases has not been published by the CDC for the years 2011 and 2012, and therefore the national incidence cannot be calculated for those years.

To obtain the number and percentages for case classification, gender, race, ethnicity, age, county and state of exposure, exposure to a tick habitat, tick bite history, and the number of cases with clinical symptoms of Spotted Fever Rickettsiosis, the PROC FREQ procedure in SAS 9.2® was utilized.

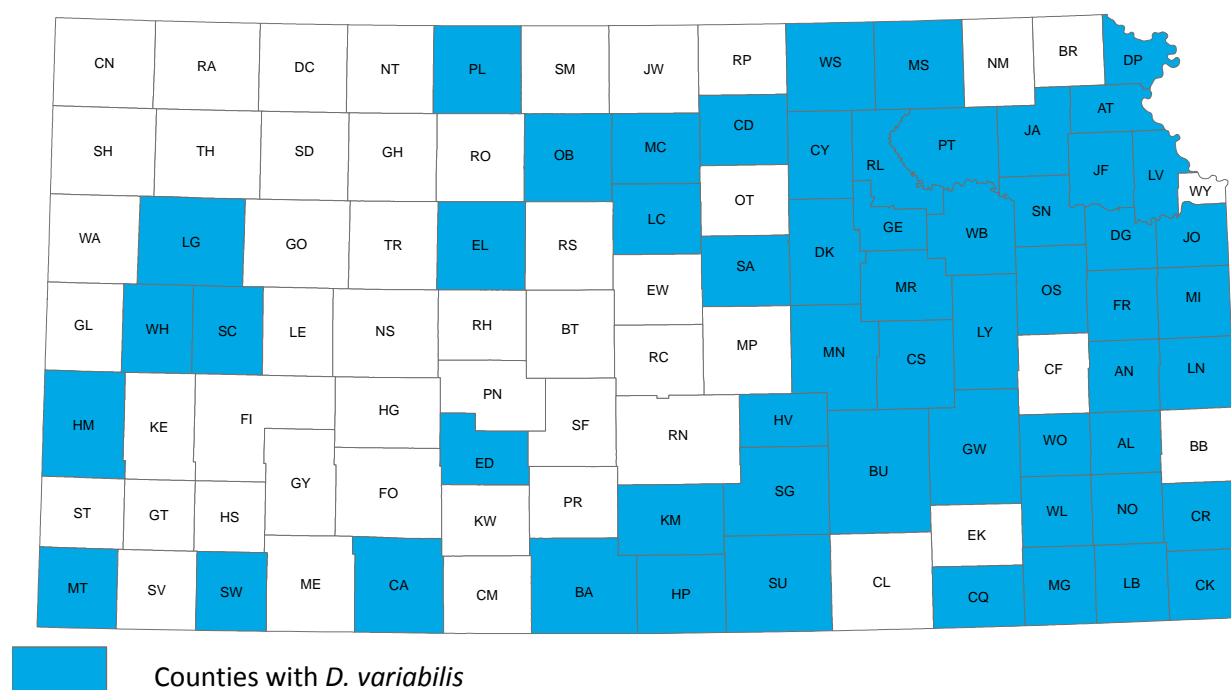
## Results

### Tick Vector Locations

*Dermacentor variabilis* has been identified in 57 (54%) Kansas counties. Distribution of *D.*

*variabilis* is seen throughout the state, expanding as far west as Morton and Hamilton County, and as far north as Marshall, Washington, and Phillips County. A majority of the counties with this tick are in the eastern region of the state, Figure 14. *R. sanguineus* ticks were located in four counties in different regions of the state, Figure 15.

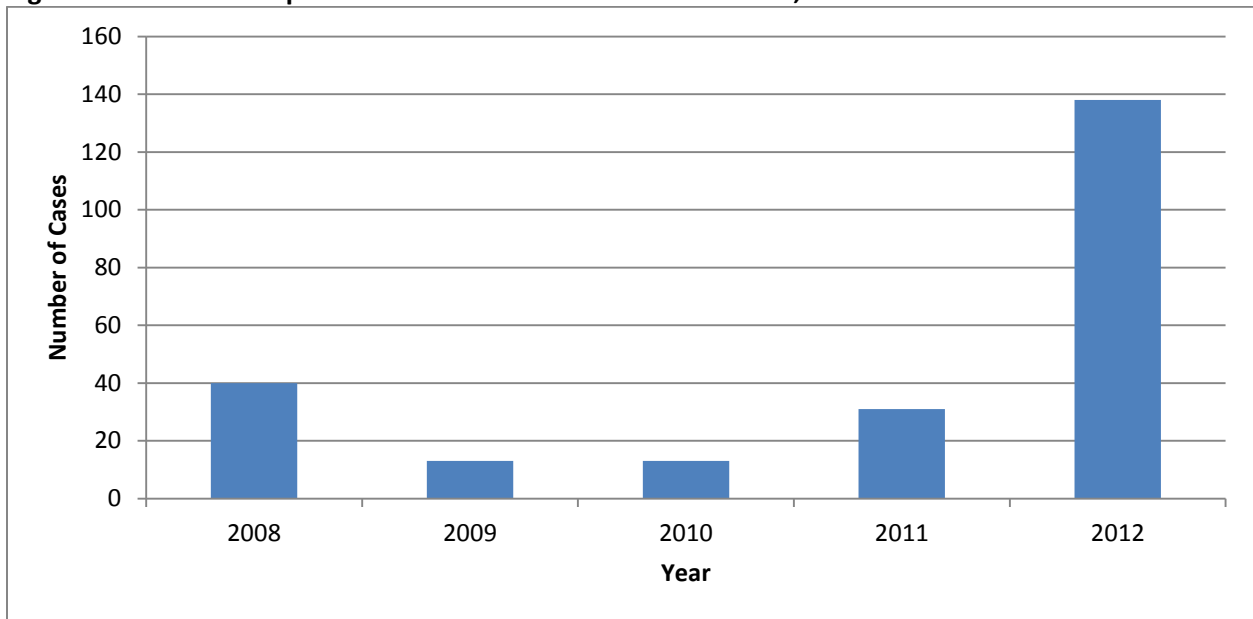
**Figure 14: Map of Counties in Kansas where *Dermacentor variabilis* ticks were found.**



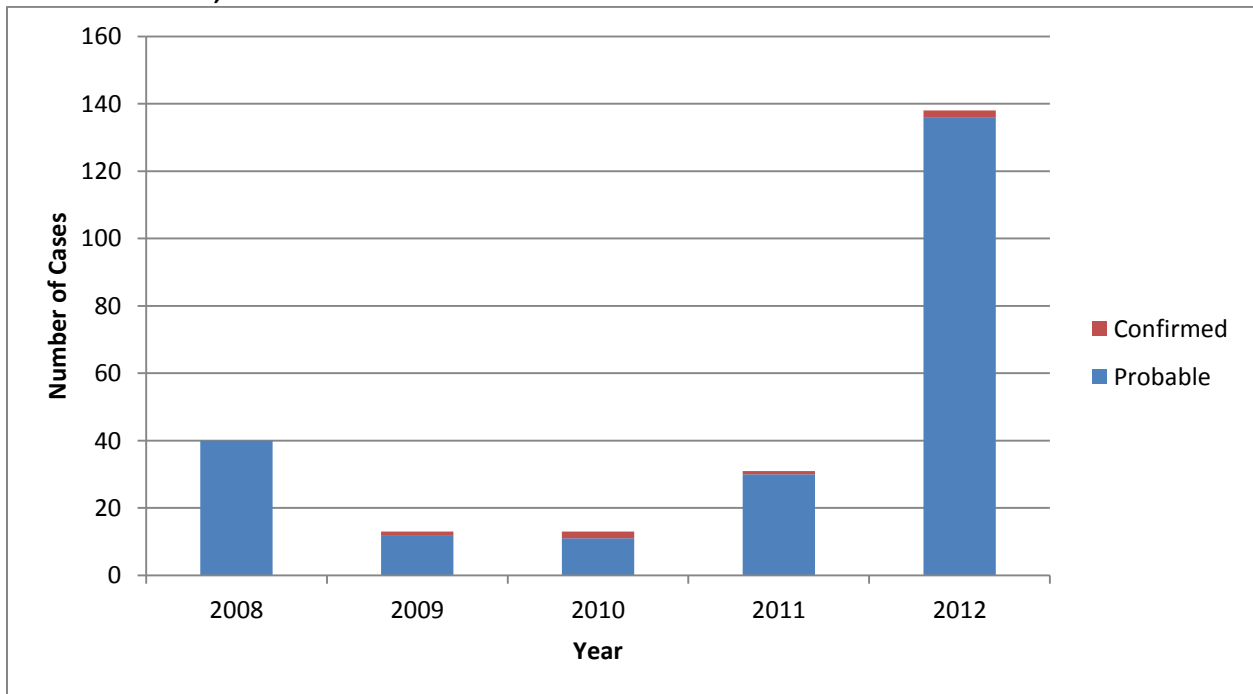
Counties with *R. sanguineus*

From 2008 to 2012, 235 cases of Spotted Fever Rickettsiosis have been reported in Kansas. There were 40 cases in 2008, 13 cases in 2009, 13 cases in 2010, 31 cases in 2011, and 138 cases in 2012, Figure 16. In 2008 there were no confirmed cases and 41 probable cases, one confirmed case and 11 probable cases in 2009, three confirmed cases and 13 probable cases in 2010, no confirmed cases and 30 probable cases in 2011, and two confirmed cases and 134 probable cases in 2012, Figure 17. There was a large increase in probable cases in 2012, up 485%, indicating a four-fold increase from the average number of cases reported during 2008 to 2011.

**Figure 16: Number of Spotted Fever Rickettsiosis Cases in Kansas, 2008-2012.**

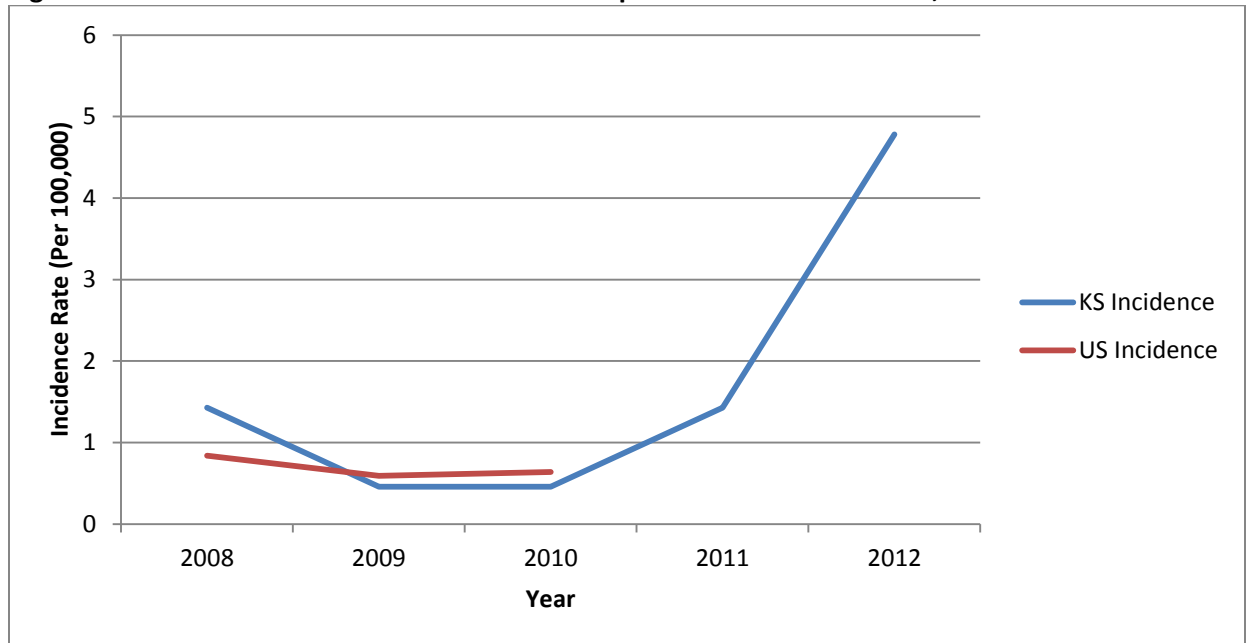


**Figure 17: Number of Confirmed and Probable Cases of Spotted Fever Rickettsiosis Reported in Kansas, 2008-2012.**



The incidence per 100,000 in the United States was 0.84 in 2008, 0.59 in 2009, and 0.64 in 2010, Figure 19. In Kansas, the incidence was 1.43 in 2008, 0.46 in 2009, 0.46 in 2010, 1.43 in 2011, and 4.78 in 2012.

**Figure 18: United States and Kansas Incidence of Spotted Fever Rickettsiosis, 2008-2012.**

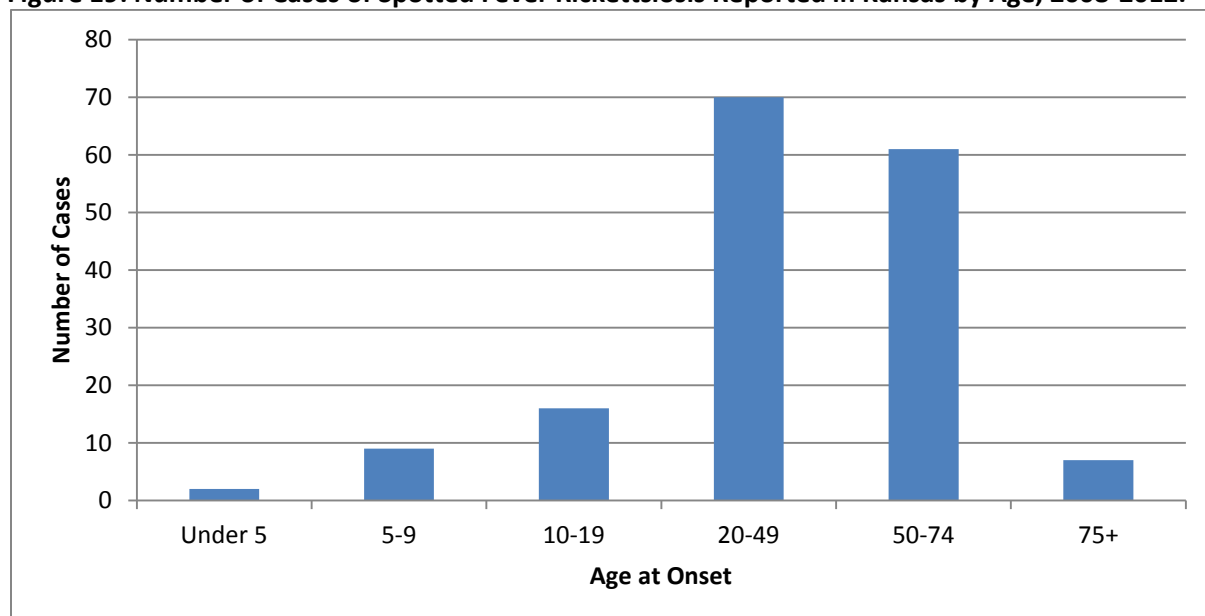


From 2008 to 2012 there were more male cases of Spotted Fever Rickettsiosis reported than female cases, Table 3. Race was reported for 193 cases from 2008 to 2012; race was not reported and is considered unknown for 42 cases. The predominant race affected was White. Only one case of Spotted Fever Rickettsiosis was reported for Black/African-American, Asian, American Indian/Alaskan Native and White/American Indian, Table 3. Ethnicity was reported for 180 Spotted Fever Rickettsiosis cases from 2008 to 2012, ethnicity was not reported and is considered unknown for 55 cases, Table 3. There was significantly more non-Hispanic or Latino individuals with Spotted Fever Rickettsiosis than individuals of Hispanic or Latino ethnicity, Table 3.

**Table 3: Demographic Characteristics of Spotted Fever Rickettsiosis Patients in Kansas, 2008-2012.**

Demographic	Number	Percentage
<b>Sex</b>		
Male	147	62.55
Female	88	37.45
<b>Race</b>		
White	189	80.43
Black/African American	1	0.43
American Indian/Alaskan Native	1	0.43
White; American Indian/Alaskan Native	1	0.43
Asian	1	0.43
Unknown	42	17.87
<b>Ethnicity</b>		
Non-Hispanic or Latino	173	73.62
Hispanic or Latino	7	2.98
Unknown	55	23.4

From 2008 to 2012 Spotted Fever Rickettsiosis was most commonly reported in adults 20 to 49 years old and adults 50 to 74 years old, Figure 19. Very few cases were reported in children from 0 to 19 years old and in the elderly (those 75 years or older), Figure 19. There were 70 cases that did not have a documented onset date, and therefore age at onset was not calculated.

**Figure 19: Number of Cases of Spotted Fever Rickettsiosis Reported in Kansas by Age, 2008-2012.**

The most commonly reported symptoms reported by patients diagnosed with Spotted Fever Rickettsiosis were fever, myalgia, headache, and rash, Table 4. Other symptoms reported included elevated liver enzymes, anemia, leukopenia, thrombocytopenia, and eschar.

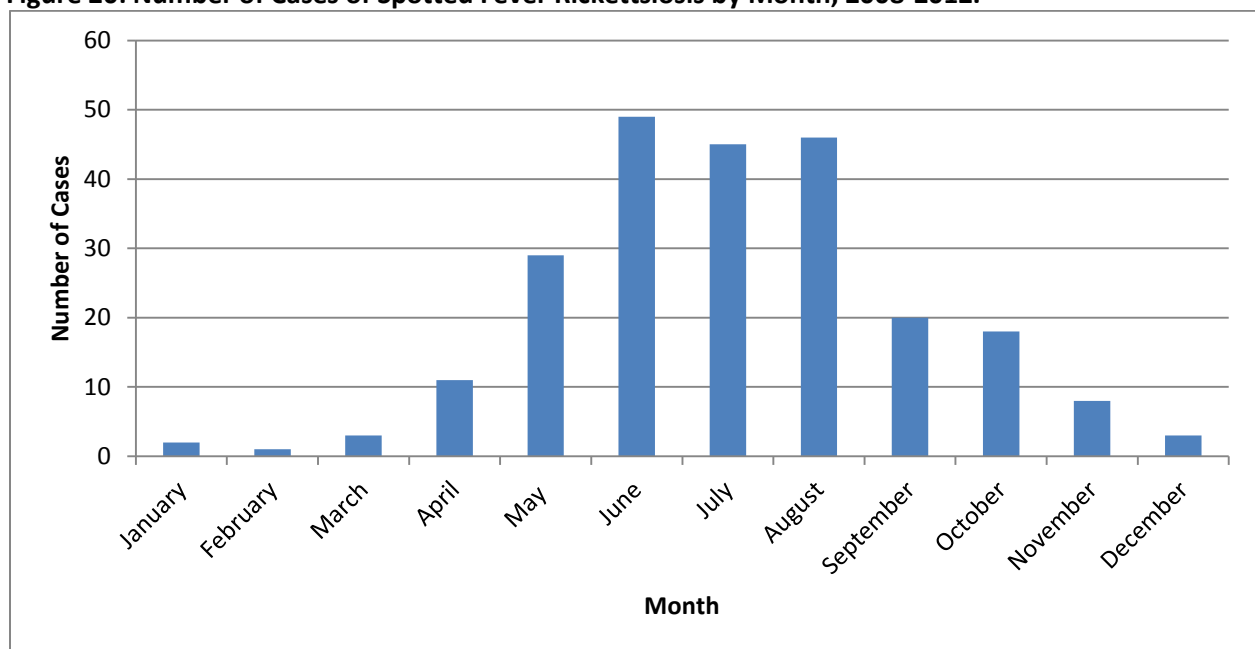
There were 61 patients (29%) that were hospitalized and hospitalization was unknown for 26 patients (11%). There were no deaths associated with Spotted Fever Rickettsiosis from 2008 to 2012.

**Table 4: Symptoms Displayed in Spotted Fever Rickettsiosis Patients.**

Symptoms	# Yes's	Total Known	Percentage
Fever	225	228	98.7
Myalgia	172	214	80.4
Headache	162	211	76.8
Rash	97	209	46.4
Elevated Hepatic Transaminases	31	133	23.3
Anemia	28	160	17.5
Leukopenia	25	150	16.7
Thrombocytopenia	24	145	16.6
Eschar	4	205	2.0

A majority of Spotted Fever Rickettsiosis cases were reported from May to October for 2008 to 2012, displaying a late spring to early fall seasonality, Figure 20.

**Figure 20: Number of Cases of Spotted Fever Rickettsiosis by Month, 2008-2012.**



A total of 46 counties (44%) in Kansas had a confirmed and/or probable case of Spotted Fever Rickettsiosis that reported exposure in that county from 2008 to 2012, Figure 21.

As part of the case investigation, individuals diagnosed with Spotted Fever Rickettsiosis were asked whether they had an exposure to a tick habitat prior to the onset of illness. There were 122 cases (52%) reported exposure, 16 cases (7%) reported no exposure, and 97 cases (41%) were unknown either because they were not available to be interviewed, were not interviewed by the local health department, or were unable to recall if they had been in potential tick habitat prior to their onset of illness, Figure 22. Also, 108 individuals (46%) reported history of a bite prior to illness, 97 individuals (41%) reported no history of a bite, and 30 individuals (13%) either could not recall if they had been bitten by a tick or were not interviewed, Figure 23.

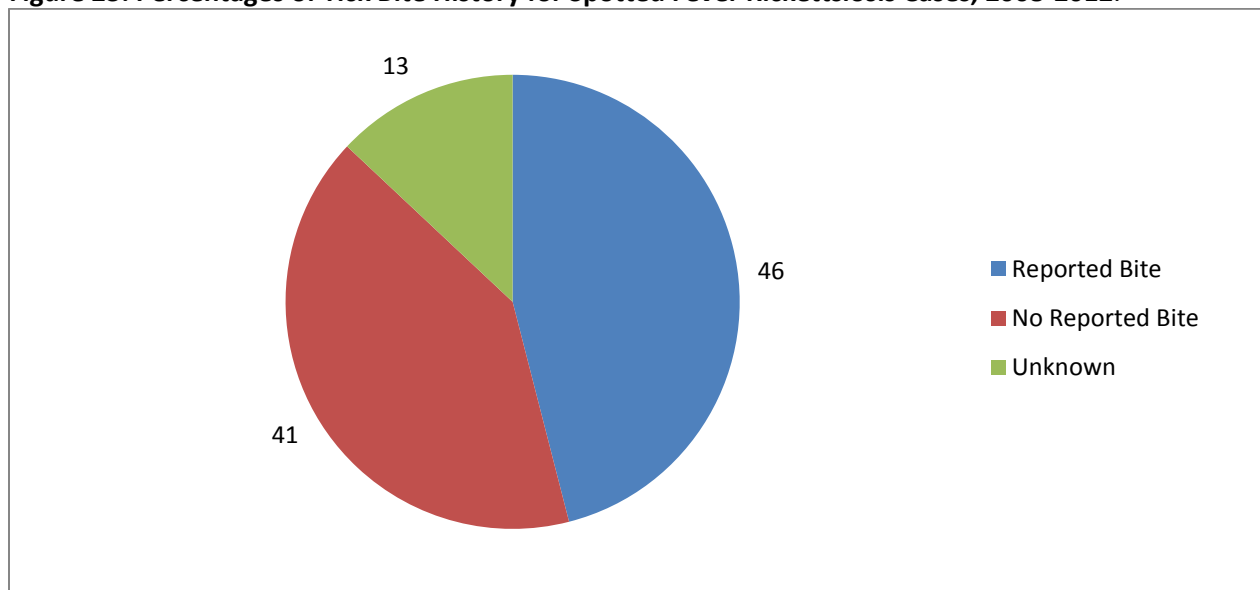


Counties of Exposure for Confirmed or Probable Cases

A pie chart illustrating the distribution of responses for the question 'Do you have a good idea of what you want to do?'. The chart is divided into three segments: a large blue segment representing 'Yes' at 52%, a small red segment representing 'No' at 7%, and a large green segment representing 'Unknown' at 41%. A legend to the right of the chart identifies the colors: blue for 'Yes', red for 'No', and green for 'Unknown'.

Response	Percentage
Yes	52
No	7
Unknown	41

**Figure 23: Percentages of Tick Bite History for Spotted Fever Rickettsiosis Cases, 2008-2012.**



## Discussion

### Descriptive Epidemiology

There appears to be a near statewide distribution of the *Dermacentor variabilis* tick in Kansas, although there appears to be more counties in the eastern part of the state with *D. variabilis* ticks. This may be due to the tick's habitat. *D. variabilis* habitat includes wooded areas, abandoned fields, medium height grasses and shrubs, and sunny or open areas around woods (Sonenshine, 1991). This would not be consistent with the habitat in many of the far Western counties in Kansas.

The *Rhipicephalus sanguineus* tick vector, does not appear to be endemic in the state of Kansas, and was found in only 4 counties in Kansas. Therefore, it is unknown how much of a role this tick plays in the transmission of Spotted Fever Rickettsiosis in Kansas.

The distribution of confirmed and probable cases of Spotted Fever Rickettsiosis in counties is very similar to the counties where both *D. variabilis* and *R. sanguineus* ticks have been reported. The 10

counties that have cases reporting exposure yet have not had either the *D. variabilis* or *R. sanguineus* tick vector in that county are adjacent or in close proximity to counties where these ticks are located. Therefore, it is likely that these counties may have *D. variabilis* or *R. sanguineus* ticks present but they have not been identified and reported yet.

In 2012, there was a large increase in the number of cases reported compared to each year from 2008 to 2011. This marked increase may be due to several factors. In August of 2011, the KDHE had a change in their surveillance protocols. This change may have resulted in an increase in the investigation of these cases where clinical symptoms were collected and reviewed. Many of the cases that were originally considered suspect became probable, based on reviews of clinical and laboratory evidence by the staff at the KDHE. Additionally, the KDHE switched from the EDSS surveillance system to the current EpiTrax system where there are new surveillance protocols in place so that specific variables associated with a case can now be more easily reviewed and may have led to this increase in the number of probable cases seen in 2012. The number of confirmed cases has remained stable but low throughout the study period.

There was a much higher percentage of probable cases than confirmed cases reported from 2008 to 2012. The large percentage of probable cases each year most likely is the lack of the appropriate laboratory testing needed for a confirmatory classification. Most clinicians will order an IFA when a patient presents with a clinically compatible case of Spotted Fever Rickettsiosis. To be considered confirmed based, on the CDC case classification a four-fold change must be observed between paired serum samples, one drawn during the first week of clinical illness and the second sample taken 2 to 4 weeks later. Many patients will not typically return to their doctor to have a follow up blood draw for the follow up antibody testing. Therefore, many cases will remain as a probable case classification.

The incidence of Spotted Fever Rickettsiosis in Kansas was slightly higher than the incidence in the United States in 2008. CDC has reported the incidence of RMSF in the United States has increased significantly in the last decade. In 2000, the reported incidence was less than 2 cases per million people, and in 2010 the incidence rate rose to over 6 cases per million people in the United States. This increase in incidence in the United States has been attributed primarily to exposure to the tick vector *R. sanguineus* due to the frequent contact between humans and dogs, which are the primary host for *R. sanguineus* (CDC, 2012). Since there have been very few identified *R. sanguineus* ticks in Kansas, it would suggest that the increase in Spotted Fever Rickettsiosis cases in Kansas is not due to the *R. sanguineus* tick. In Kansas, it is more likely that the primary tick vector responsible for the transmission of Spotted Fever Rickettsiosis is *D. variabilis*.

A majority of Spotted Fever Rickettsiosis cases from 2008 to 2012 were reported in white individuals, with very few cases reported in other races. This is similar to the breakdown in the population of races in Kansas. The U.S. Census Bureau, in 2011, reported that 87.4% of the total Kansas population are white, while only 6.1% of Kansans are black, 2.5% are Asian, 1.2% are American Indian/Alaska Natives, and .1% are Pacific Islander (U.S. Census Bureau, 2011).

Interestingly, it is important to note that there were more males than females that were reported with Spotted Fever Rickettsiosis from 2008 to 2012. Further research is needed to understand the uneven dispersion of this disease between males and females in Kansas. It was also seen that there were more cases of Spotted Fever Rickettsiosis reported in individuals 20 years to 74 years old. This could be the result of prolonged outdoor activity in woody and brushy areas or participation in agricultural and farming work, allowing for greater outdoor exposures, which are major risk factors in contracting Spotted Fever Rickettsiosis.

The most common symptoms that were displayed by patients were very non-specific, with fever, myalgia, and headache being the top three symptoms reported to public health officials. Non-specific clinical signs may delay diagnosis and treatment because individuals may not realize they are infected with Spotted Fever Rickettsiosis.

The seasonality of Spotted Fever Rickettsiosis cases shows an expected trend. Most cases are seen between April and October when the ticks are more active and seeking a blood meal and when there is greater outdoor activity.

Over half of all Spotted Fever Rickettsiosis cases from 2008 to 2012 reported exposure to potential tick habitats, such as grassy, weedy, or brushy areas and a little less than half reported a tick bite. While some individuals diagnosed with Spotted Fever Rickettsiosis did not report exposure to potential tick habitats, it could be likely that these individuals either did not correctly recall where they had been in the preceding two weeks or they came into contact with a tick in an area not normally considered to be suitable for maintaining populations of these tick vectors. It is not surprising that a little less than half of the individuals diagnosed with Spotted Fever Rickettsiosis did not recall being bitten by a tick. Many tick species are very active during the nymph life stage, and because they are small they can be easily overlooked.

# Chapter 4: Conclusions

## Study Limitations

As is common with passive surveillance methods there is the likelihood of underreporting. The KDHE relies on clinicians, laboratories, and hospitals to report cases of Lyme disease and Spotted Fever Rickettsiosis, therefore it is unknown if all cases of these diseases are actually diagnosed and reported. Tick surveillance relied on submissions of ticks from a variety of sources for identification so there is the possibility that ticks could be in other counties than those identified in this paper. Kansas is a decentralized state and the responsibility lies with each local health department to investigate cases of infectious diseases in their counties. Incomplete investigations do affect the classification of both Lyme disease and Spotted Fever Rickettsiosis cases because each case's clinical information as well as exposure information all aid in proper case classification. Since Lyme disease and Spotted Fever Rickettsiosis are both tick-borne diseases and are not spread person to person, many health departments might prioritize the investigations of these cases lower than those reportable diseases that can be spread by person to person contact. In addition, each county health department has different staffing levels with competing priorities that could affect the level and thoroughness of case investigations. The county of exposure is collected when the case is interviewed, and has several limitations; the case may not recall the place and exposures that they may have had up to thirty days prior to disease onset. Changes in surveillance and classification methods can also result in changes in reporting disease incidence and may not represent a true change in disease incidence.

## **Recommendations**

One of the recommendations for helping maintain more accurate and comprehensive records on tick species distribution in Kansas is to more fully utilize the extension agents in each county. These extension agents are equipped and capable of identifying tick species, and currently perform this task for members of the community. However it is commonplace that no records are kept with the name or address of the person who brought in the tick, nor do they keep track of the species of ticks or the life stage when it was identified. This is a missed opportunity for data collection that would benefit health departments, county extension agents, and other tick research being conducted by professors or researchers in Kansas. Further recommendations can be made, such as providing training and assistance to local health departments during an investigation for tick-borne diseases. It may also be beneficial to provide more information to health care providers on the appropriate confirmatory tests to order, when considering the diagnosis of a tick-borne disease like Lyme or Spotted Fever Rickettsiosis.

## **Education**

When opportunities become available, educational materials or lectures should be provided, especially during the summer months when tick-borne disease transmission is at its peak. Education materials should include information regarding the seasons in which people are most likely to contract Lyme disease or Spotted Fever Rickettsiosis, activities of greater risk for contracting a tick-borne disease, signs and symptoms, images depicting the tick vectors for identification purposes, and prevention measures. Prevention measures such as wearing protective clothing, using tick repellents, and checking for ticks after outdoor activities can all reduce the risk of contracting a tick-borne disease. Other prevention measures that should be promoted include keeping yards mowed and clear of excessive leaves, brush, and other tall grasses.

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